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AFCRL-62-375

# ATC LINAR RECEIVER

by

W. F. Fickenscher

THE BENDIX CORPORATION  
BENDIX RADIO DIVISION  
BALTIMORE 4, MARYLAND

Contract No. AF19(604)-8848

Project No. 4655

Task No. 46550

## FINAL REPORT

30 May 1962

Prepared  
for



ELECTRONICS RESEARCH DIRECTORATE  
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES  
OFFICE OF AEROSPACE RESEARCH  
UNITED STATES AIR FORCE  
BEDFORD, MASSACHUSETTS

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## FOREWORD

This report is the final report and covers the work done at Bendix Radio under contract AF19(604)-8848 for The Electronics Systems Division, Air Force Systems Command (Laurence G. Hanscom Field, Bedford, Massachusetts). This report discusses the work done during the last period and the instructions for operating the finalized ATC LINAR Receiver.

### ABSTRACT

The purpose of the program was to produce a LINAR receiver which will be compatible to the MPN-11 radar system. The program commenced on 10 July 1961 and was completed on 30 May 1962. A prototype model was built and tested and from these tests a final model was built and has been delivered to ESD (ESSVM). In producing the final model a few problem areas were encountered that are discussed in section 2. It was also necessary to make several trips to Hanscom AFB to make the system compatible to the MPN-11 radar system. A description of the final receiver is discussed in the last section of this report to present to the reader a description of the final model and how to operate this final receiver.

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## 1. INTRODUCTION

The basic problems encountered in ground control approach radar systems are visibility in clutter areas and visibility during weather. The standard tools with which the operator can combat these problems are MTI (Moving Target Indicator Receiver), STC (Sensitivity Time Control), FTC (Fast Time Constant), and a manual gain control. Each has definite limitations on its usefulness. MTI exhibits blind speeds and is difficult to keep in proper adjustment. Both STC and gain control reduce the amplitude of targets as well as undesired signals. The use of a fast time constant circuit reduces the width of clutter signals, but sensitivity to targets is retained only when clutter amplitude is small (below limiting in the final IF stages and detector). Consequently, only when gain is reduced does it improve target visibility.

The Bendix LINAR receiver produces an output containing most of the good features of all the above operations, and it was the purpose of this contract to adapt such a receiver to the MPN-11. The ATC LINAR achieves extremely high sub-clutter visibility without the problem of blind speeds. This is done with a wide dynamic range linear detector followed by differentiation.

While the clutter is not entirely removed, as is the case in an MTI receiver, maximum sensitivity is retained to signals atop it. In addition, all clutter pulses of a longer duration than a target are rejected through pulse width discrimination. This leaves a residue of spikes from clutter on the indicator, but it is not sufficient to interfere with tracking.

Where in the case of the standard FTC, targets were visible only when gain was reduced to a level where the clutter was not limited, the LINAR receiver FTC requires no gain reduction because the detector does not limit. This means that targets are tracked at maximum sensitivity whether they are in the clear or in clutter.



Against weather the only useful device in the standard system is the gain control. By reducing sensitivity the operator may be able to track targets. With the LINAR, no manual gain control adjustment is necessary to optimize on targets in weather. That is, the receiver video gain changes to prevent indicator saturation. Any target that is larger than the noise component of the weather return will be presented.

The LINAR adds somewhat to the capabilities of the system. However, its primary advantage is that it simplifies the system operation. It allows the operator to track as well with no adjustment of controls as he formerly could by varying gain, etc. It allows tracking of several targets simultaneously with maximum sensitivity for each. Also, maintenance should be kept to a minimum since the device is completely transistorized.

## 2. DISCUSSION OF WORK DONE

### 2.1 PURPOSE

The purpose of the program was to develop a LINAR receiver which was compatible with the MPN-11 precision radar system. The primary objectives were to provide sub-clutter visibility, weather rejection, and high resolution. A prototype was built and tested during the last quarter and a final model was built and delivered to AFCS in May 1962. (See Figure 1.)

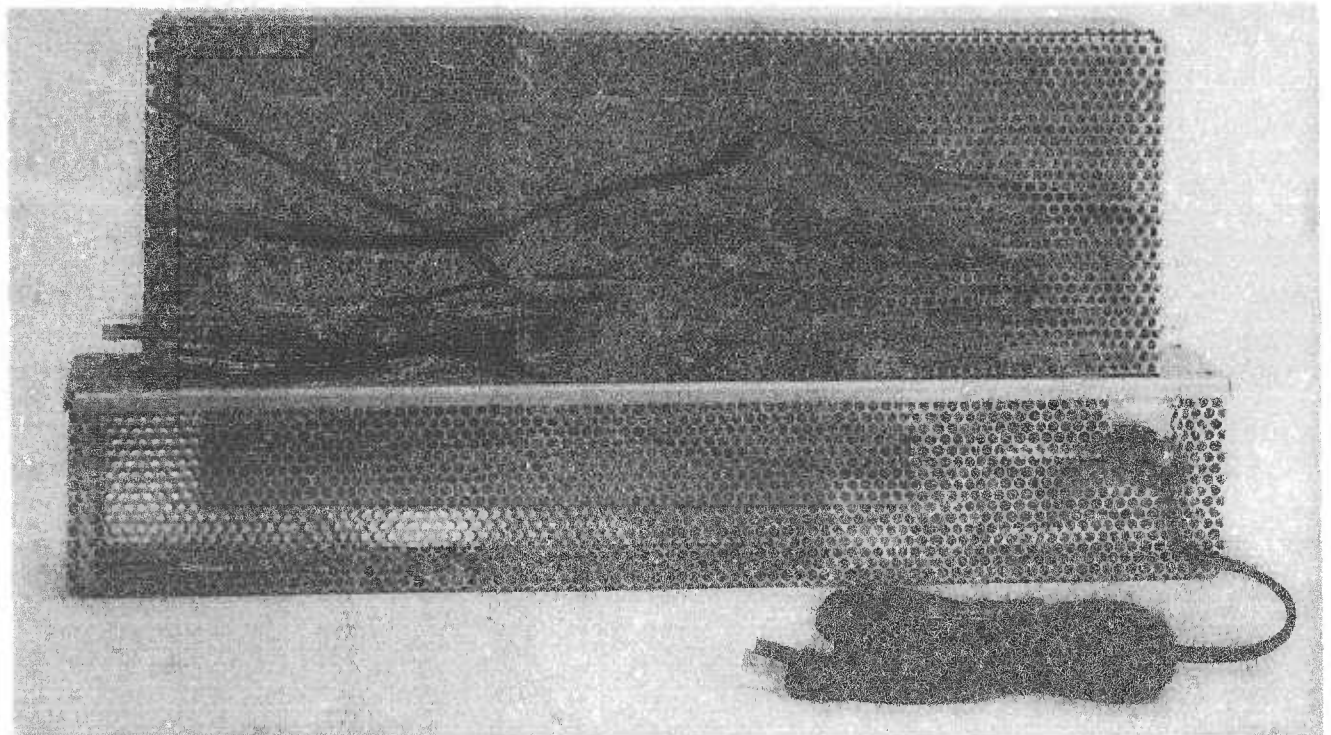


Figure 1. ATC LINAR Receiver

### 2.2 MAJOR PROBLEMS AND SOLUTIONS

The major difficulties encountered in adapting the Bendix LINAR receiver to air traffic control use were in wide-banding the basic circuits. The original LINAR receiver design was for narrow bandwidth search radars and

it was necessary to improve the response considerably, particularly of the integrators which are used in the signal line.

Another problem was the necessity of producing an extremely fast differentiation without an appreciable loss of sensitivity. This was achieved with a series R-L-C circuit. After a leading or trailing edge of a signal, the FTC returns to the base line in approximately twice the pulse rise time.

The original design called for a single detector with a wide dynamic range. After some testing it was determined that optimum operation of the receiver demanded a truly linear detector with a wide dynamic range. The Bendix linear receiver (O. H. Baust, 15 March 1960, T-11, 229-5) was such a device. The idea of several parallel detectors was incorporated into the LINAR, and the IF and detector circuits, were designed and tested.

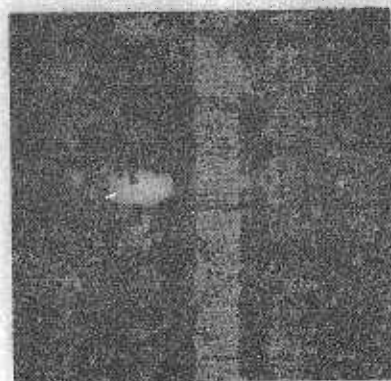
A further problem was encountered in the 30-MC leakage through the detector stages after they became saturated. For linear detector action this is not tolerable. A filter was added to each detector consisting of a toroid and a capacitor. This afforded the proper bandwidth necessary for video while rejecting the undesired 30-MC signals.

The packaging of the receiver into the space occupied by the normal receiver was specified in the contract. The receiver was installed on the MPN-11 and was found to mount easily.

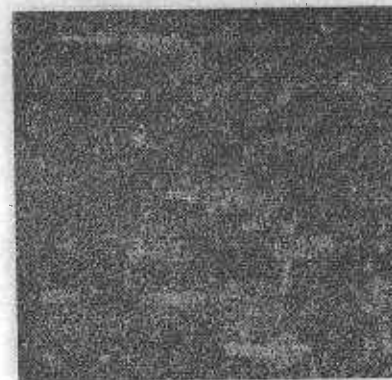
The receiver which has been developed is currently being tested and evaluated at AFCS headquarters, Scott AFB, Illinois. Section 3 of this report will deal with the operation and maintenance of the receiver itself in order to facilitate the testing and aid in evaluation. Photographs were taken at Hanscom AFB, Massachusetts showing the ability of the LINAR receiver. The first pair of pictures (Figure 2) shows the ability of the Bendix ATC LINAR to break up the clutter as compared to the normal receiver. In the succeeding pictures (Figures 3 and 4), which were taken over several indicator scans, the sensitivity of the LINAR is illustrated. The targets are readily tracked through



the clutter area. For all the multi-scan pictures, the gain control was set for maximum sensitivity and not adjusted.



SYSTEM NORMAL  
RECEIVER  
MPN-11



BENDIX LINAR  
RECEIVER

Figure 2, Photographs of Single Scan

### 2.3 ADMINISTRATION

The work performed on this contract was under the direction of Mr. J. Martin. During the first quarter, the design engineer was Mr. O. Baust, and thereafter his duties were transferred to Mr. W. Fickenscher. The mechanical design work was done by Mr. J. Baker, Mr. J. Bode, and Mr. L. Bosse assisted the above group.

### 2.4 TRAVEL

Several trips were involved in producing the receiver. Early in the contract Mr. Baust and Mr. Baker made trips to Hanscom AFB to gather the necessary information for adapting the receiver to the MPN-11. During the last quarter Mr. Baust and Mr. Fickenscher performed tests with the prototype

at Hanscom, and later, Mr. Martin accompanied several others to oversee the acceptance testing of the final model.



BENDIX LINAR  
RECEIVER  
(TARGET 5-7MILES)  
T-33



BENDIX LINAR  
RECEIVER  
(TARGET ON RUNWAY)



SYSTEM NORMAL  
RECEIVER  
MPN-11

Figure 3. Photographs of Multi-Scans with Target on Runway and 5-7 Miles Away



SYSTEM NORMAL  
RECEIVER  
MPN-11  
(TARGET IN CLOSE)



BENDIX LINAR  
RECEIVER  
(TARGET IN CLOSE)  
T-33



BENDIX LINAR  
RECEIVER  
(TARGET IN CLOSE)

Figure 4. Photographs of Multi-Scans with Target in Close



### 3. DESCRIPTION OF FINAL EQUIPMENT

#### 3.1 THEORY OF OPERATION

The Bendix ATC Receiver is designed to combat some of the major problems encountered in ATC radars. These include clutter, weather, and interfering radar returns.

Subclutter visibility is obtained by differentiation immediately after detection by a wide dynamic range linear detector. Clutter amplitude does not affect sensitivity to small targets as long as the dynamic range (approximately 60 DB) is not exceeded. Tracking is facilitated because the receiver removes the low frequency components of the clutter, allowing only the high frequency clutter fluctuations to pass. The remaining clutter profile is jagged and contains numerous holes. Due to the linear detector, targets are tracked through this residue at maximum sensitivity. Some of the remaining clutter spikes as well as improper length radar signals are rejected in a pulse width discrimination circuit.

Weather rejection is obtained with a video CFAR (constant false alarm rate) circuit which retains sensitivity to targets larger than the noise component of the weather. In addition to the above capabilities, the receiver contains a normal receiver output which can be used separately or simultaneously with the ATC LINAR output.

#### 3.2 MECHANICAL INFORMATION

The Bendix LINAR Receiver is designed to replace the normal receiver on the MPN-11. It mounts in the same location as the old normal receiver. The unit is completely transistorized and contains its own power supplies. AC is applied through a connector near the bottom of the chassis. There are three coaxial cable connections. The input and the normal receiver output are the same as the existing normal receiver cables. The third is the ATC LINAR output which connects to the video switch chassis, paralleling the normal output.

### 3.3 ANALYSIS OF OPERATION

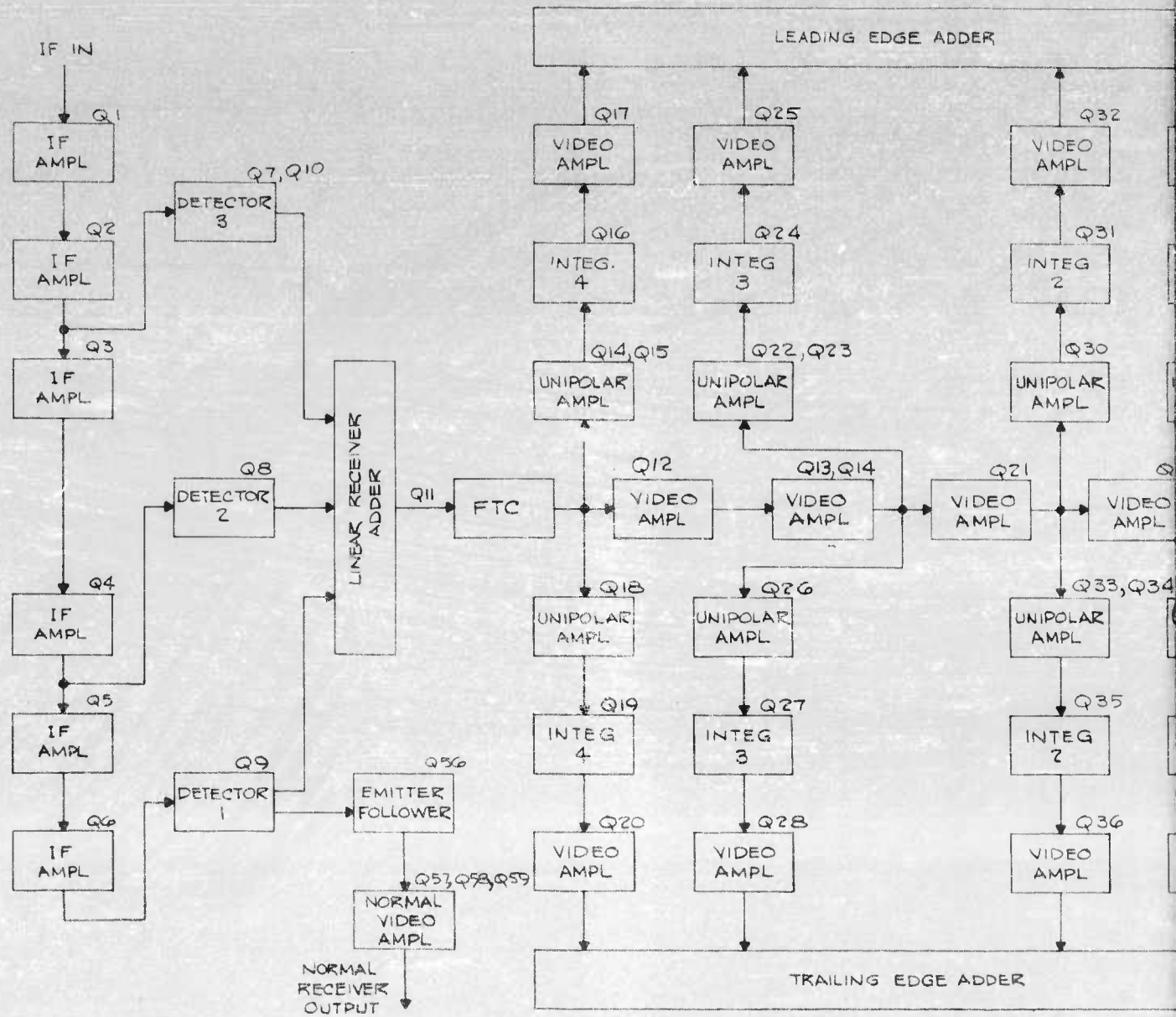
In the following description references will be made to the simplified block diagram, Figure 5, as well as the schematic diagram Figure 6. 30-MC signals from the preamplifier are applied to the first of six cascaded common base stages, Q1 through Q6. The bias circuits for these tuned stages include thermistors for temperature stability. For Figure 6 see back cover.

The output of the final IF stage (Q6) is transformer coupled to detector 1 (Q9). Detection occurs in Q9 when bias is adjusted for Class "B" operation. The bias control is R50. Associated with Q9 is a 30-MC trap for filtering and gain pot R52. The dynamic range of the detector is about 20 DB. That is, small signals are detected, but signals more than 20 DB above system noise level cause the stage to saturate.

For signals large enough to saturate detector 1, the level is great enough to be detected at the output of Q4 by detector 2, Q8. This stage is identical to detector 1, but its dynamic range covers signals over a 20-DB range which starts where that of detector 1 ends.

Similarly, detector 3 (Q7) takes over for still larger signals. The outputs of the three detectors are combined in a weighted adder circuit so that the gain to any signal is equal regardless of the path from the input to the linear receiver adder. To adjust the gain of the three channels so that linearity can be obtained, gain controls R52, R45, and R36 are located in channel 1, 2, and 3 respectively. The linear receiver adder utilizes the dynamic range of all three detector channels so that small signals and system noise remain essentially the same size regardless of the amplitude of the clutter pulses they ride upon.

From the adder, signals pass through another filter section and into an emitter follower (Q11) which drives the differentiator (FTC). Gain pot resistor (R57) sets the level for the video CFAR circuit which follows.





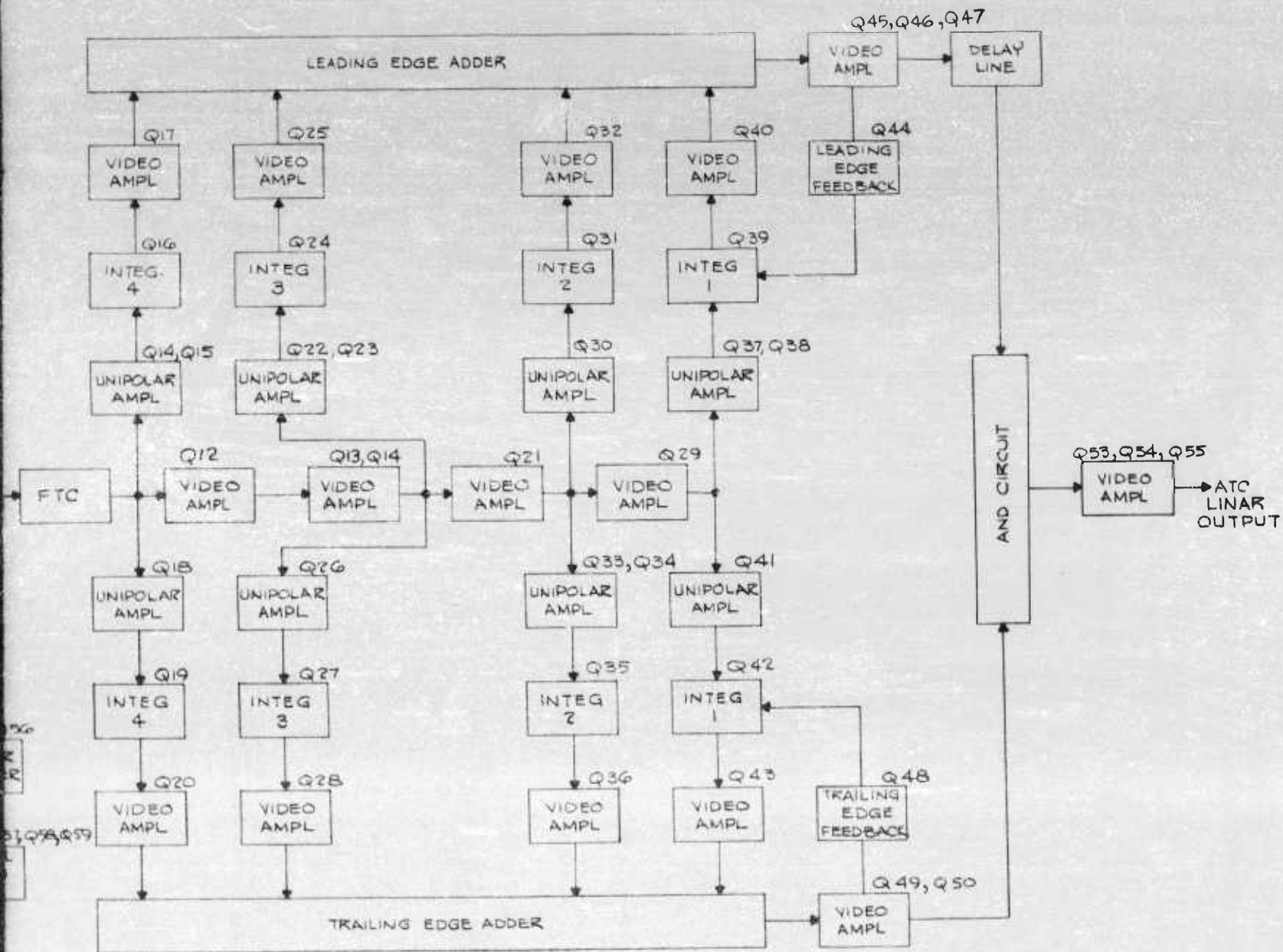


Figure 5. ATC LINAR Receiver, Block Diagram

The differentiator time constant is adjusted for rapid return to the base line after a large leading or trailing edge. At this point in the circuit, leading or trailing edges of all clutter spikes and signals will appear in linear relationship to their input amplitude. Effects of CW jamming have been removed by differentiation without loss of sensitivity to signals. Weather or noise jamming, however, will cause an increase of noise level that is directly proportional to the input amplitude.

The video CFAR (constant false alarm rate) circuitry is designed to remove fluctuations in the output noise level due to weather or noise jamming while retaining sensitivity to any signal larger than the noise. It consists of four cascaded video amplifier stages (Q13, Q14, Q21, and Q29) which drive various taps as shown in the block diagram. System noise and small signals are amplified through this chain. The output of the final stage (Q29) feeds two transistors, Q37 and Q41. Q37 is an inverter, and the remainder of the channel it feeds, Q38, Q39, and Q40, is identical to the other channel consisting of Q41, Q42, and Q43. Amplifiers Q38 and Q41 each clip off the positive portion of the input signals. For Q41, this means that only trailing edges of clutter and target pulses are passed, since signals at the linear receiver adder are positive. Due to inversion in Q37, Q38 clips off trailing edges but passes leading edges. The output of Q38 feeds emitter follower Q39, which in turn drives an integrator circuit consisting of CR13, C62, and several resistors. The integrator charges quite rapidly and discharges somewhat slower. It couples directly to the base of amplifier Q40. The receiver is adjusted so that system noise and small signals are integrated just enough to bias Q40 almost to cut-off. If the noise level increases, the integrator increases the bias and Q40 turns off.

As the noise level increases enough to cut off Q40, the amplitude at the base of Q32 in the next channel becomes large enough for it to produce an output. A further increase in noise level causes Q32 to be biased off and the



next channel to produce the output. The outputs of the four similar channels are combined in the leading edge adder. Gain in the channels is adjusted by means of the pot in the collector of each output transistor, R185, R147, R113, and R73.

In the case of the linear receiver adder, all signals received the same amount of gain regardless of the path they took from input to adder. At the leading edge adder, however, the signals receive less gain through channel 2 than through channel 1, less gain through channel 3 than through channel 2, etc. The result is that when the gains are properly adjusted, the noise level at the adder will remain constant as the noise level at the input increases. The operation of the four channels feeding the trailing edge adder is identical with the action on the leading edge side. The circuitry in each channel is identical with its leading edge counterpart, except that in each channel an inverter is necessary in one side or the other so that the proper polarity signal is picked off.

The output of each adder feeds a gain controlled emitter follower and an amplifier (Q45 and Q46 on the leading edge side, and Q49 and Q50 on the trailing edge). The output of Q46 feeds the base of Q44. This stage is biased off by adjustment of R206 and conducts only when a large signal appears at the collector of Q46. The collector of Q44 is connected to integrator 1, the base of Q40. The function of this feedback stage is to discharge the integrator quickly after a large pulse so that recovery time of the receiver is minimized. In the trailing edge side, Q48 performs the same function as Q44 in the leading edge side. The collector of Q50 also drives a fast time constant circuit (C82 and R227) which removes slow shifts in the base line from bursts of noise such as weather. Signals are then applied to the "AND" circuit driver Q51.

On the leading edge side, Q46 drives a similar fast time constant, C70 and R211. Signals are then applied to the delay line driver Q47. All signals on this side of the receiver represent the leading edge of a clutter or target pulse. The delay line delays these signals one transmitter pulse length so that for a true target, the leading edge and trailing edge arrive at the "AND" circuit simultaneously.

The "AND" circuit consists of diodes CR20 and CR24 and resistors R219, R236, and R237. When a signal is present at the input to CR20 but not at the input to CR24, CR20 is cut off; but bias current still flows through CR24. This causes only a slight variation in voltage across R237. The same result is obtained if a signal appears at the input to the trailing edge of diode CR24 but not at CR20. However, when signals occur at the two inputs simultaneously, as in the case of a proper target, all current through the diodes ceases and the voltage across R237 changes considerably. This results in a rejection of improper length signals since leading and trailing edges will not occur simultaneously.

The remainder of the circuit consists of emitter follower Q53, amplifier Q54, and an output driver Q55. R240 in the emitter of Q53 provides gain control for the output video. The bias on Q54 is variable (R242) to allow base line clipping when necessary and maximum signal-to-noise ratio is adjusted by varying the bias on limiter diode CR25 with R246. Aside from the several taps, the IF section of the receiver is the same as any linear IF amplifier. After detection by Q9, the output is that of a normal receiver. The normal video output circuitry consists of an isolation follower Q56, two amplifiers Q57 and Q58, and an output driver Q59. Gain control is provided by R260 in the collector of Q57 and maximum signal-to-noise ratio is set by varying the bias on limiter diode CR26 with R267.

### 3.4 ALIGNMENT PROCEDURE

#### 3.4.1 Power Supply Adjustment

The power supply for this unit is located on the bottom of the chassis under the shelf. It should be adjusted before the unit is mounted. With DC voltmeter between negative terminal of C702 and ground, adjust R701 for -8 VDC. See Figure 7.

#### 3.4.2 IF Alignment

The IF alignment shall be performed as follows:

1. Apply a 30-MC signal to the preamplifier input (or an RF pulse into the system in front of the crystal mixer).





2. Connect signal cable from preamplifier to "IF IN" jack J1 of Bendix ATC LINAR Receiver.
3. Connect scope probe to collector of Q9. Tune T6, T5, T4, T3, T2, and T1 for maximum positive signal at this point.

### 3.4.3 Linear Detector Adjustment

Perform the linear detector adjustment as follows:

1. Set preamplifier gain slightly below maximum.
2. Set resistors R36, R38, R44, R45, and R50 to maximum counter-clockwise. Set R52 maximum clockwise.
3. With scope probe on collector of Q9, adjust R50 until noise just reaches maximum.
4. With scope probe on center arm (green lead) of R52, adjust R52 with approximately 0.3V peak noise.
5. Apply a signal as in step 1 of section 3.4.2 above. Adjust its amplitude to be about 50-60 DB larger than the smallest discernible signal at the collector of Q9.
6. Connect probe to base of Q37. Adjust R53 for fastest return to base line without overshoot after leading or trailing edge of the differentiated pulse.
7. Adjust R57 for approximately 0.2V peak-to-peak of noise at this point.
8. Apply a long pulse (10 or more microseconds in duration), as in step 1 of section 3.4.2 above. Vary the amplitude of the input signal. As the input amplitude increases, the noise level during the pulse will increase slightly and then drop off. At about 20 DB to 30 DB adjust R45 to bring it up equal to the level of the noise outside the pulse.
9. Increase the input about 20 DB further, and adjust R36 for constant level as in step 8.
10. The detector is linear when the noise level during a pulse remains constant over the entire range of input amplitude. By proper adjustment of the contribution from each detector, an essentially constant noise level can be obtained over a 60 DB range. If necessary, readjust resistors R52, R45, and R36.
11. Readjust R57 for approximately 0.2V peak-to-peak noise at base of Q37.

#### 3.4.4 CFAR Video Adjustment

The CFAR video adjustment shall be performed as follows:

1. Set resistors R73, R96, R113, R128, R147, R164, R185, R200, R206, and R232 fully clockwise.
2. Set R211 and R227 fully counterclockwise.
3. With equipment as shown in Figure 8 (scope probe on base of Q37), adjust input noise level with the attenuator until a 3-DB change on the attenuator makes a barely discernible change in the noise at Q37.

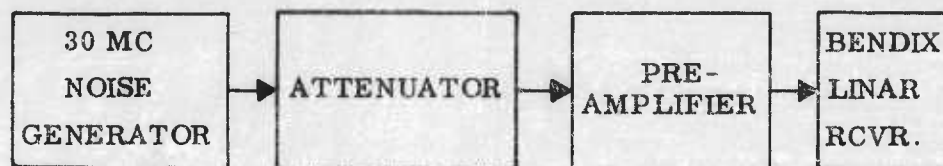


Figure 8. Test Setup for CFAR Video Adjustment

4. With scope probe on collector of Q46, adjust R250 for about 0.5V peak noise.
5. Scope probe on base of Q47. Vary the attenuator over a range of about 60 DB in 10-DB steps from the original setting (step 3). The noise level should remain essentially constant although the character or appearance of the noise may change. If the level does not remain constant, slight readjustment of R185, R147, R113, and R73 may be necessary.
6. Return to the original attenuator setting (step 3). With scope probe on collector of Q50, adjust R223 for about 0.5 volts peak noise.
7. Vary the attenuator over a 60-DB range from the original setting. The noise level should remain essentially constant. If it does not, slight readjustment of R200, R164, R128, and R96 may be necessary.
8. Remove noise generator from the input to the preamplifier. Apply a signal to the preamplifier. With scope probe on base of Q37, set the signal amplitude for the smallest discernible signal.
9. Increase the signal size by about 60 DB.
10. Scope probe on collector of Q46. Adjust R206 counterclockwise. Recovery time after the leading edge will decrease to about 1 microsecond. Beyond this point adjustment has no further affect. Set R206 just to the point of minimum recovery time.



11. Scope probe on collector of Q50. Adjust R232 counterclockwise. Recovery time after the trailing edge will decrease to about 1 microsecond. Beyond this point adjustment has no further affect. Set R232 just to the point of minimum recovery time.

#### 3.4.5 Pulse-Width Discrimination Circuitry Adjustment

The pulse-width discrimination adjustment shall be performed as follows:

1. With a large signal still applied to the input (step 9 of section 3.4.4) and scope probe on base of Q52, adjust R215 for minimum delay line reflection.
2. Accurately measure the noise level at the emitter of Q52. The level at the emitter of Q51 should be set to the same level by adjustment of R223.
3. The location of the delay line tap is determined by trial and error. The proper location of the tap is the point which gives maximum signal-to-noise ratio for a target. Since the transmitter pulse length and shape cannot be accurately duplicated, the best procedure is to aim the antenna at a fixed point target and move the tap until the point of maximum output is located.

#### 3.4.6 Video Output Circuitry Adjustment

The video output adjustments should be set for the best indicator presentation. The controls are R240 for video gain, R242 for baseline clipping, and R246 for limit level.

#### 3.4.7 Normal Receiver Adjustment

The normal receiver adjustment shall be performed as follows:

1. The IF alignment for the normal receiver output requires no additional tuning since the same IF strip is used for the normal and linear circuits.
2. Video circuit adjustments are set for best presentation on the indicator. The controls are R260 for video gain and R267 for limit level.

#### NOTE

Although all four channels contribute some noise to the adder regardless of the input noise amplitude, there is one predominant contributor for any given noise level. The following table shows the range over which each channel contributes a major portion of the noise. For example, if, in varying over the 60-DB range, the noise level increases at about 40 DB above MDS, output from channel 3 should be reduced. That is, R113 should be varied for the leading edge side, or R128 for the trailing edge side. However, if the noise level is low at about 40 DB, the other three channels should be slightly reduced.

Table 1. CFAR Video Channel Ranges

Noise Level (DB above MDS)	0-15	15-30	30-45	45-60
Primary Contributor	Channel 1	Channel 2	Channel 3	Channel 4
Adjustment for Leading Edge Side	R 185	R 147	R 113	R 73
Adjustment for Trailing Edge Side	R 200	R 164	R 128	R 96

### 3.5 SYSTEM CHECK

#### 3.5.1 Linearity Check

The linearity check shall be performed as follows:

1. Apply a 30-MC signal to the input of the preamplifier.
2. Decrease the signal to the smallest discernible signal.

3. Switch the generator to "CW" output. Increase the level gradually to about 60 DB larger than the original setting.
4. If the noise level remains essentially constant over this range, the linear receiver portion of the receiver is operating properly. If not, refer to section 3.4.3 of the alignment procedure.

#### 3.5.2 CFAR Check

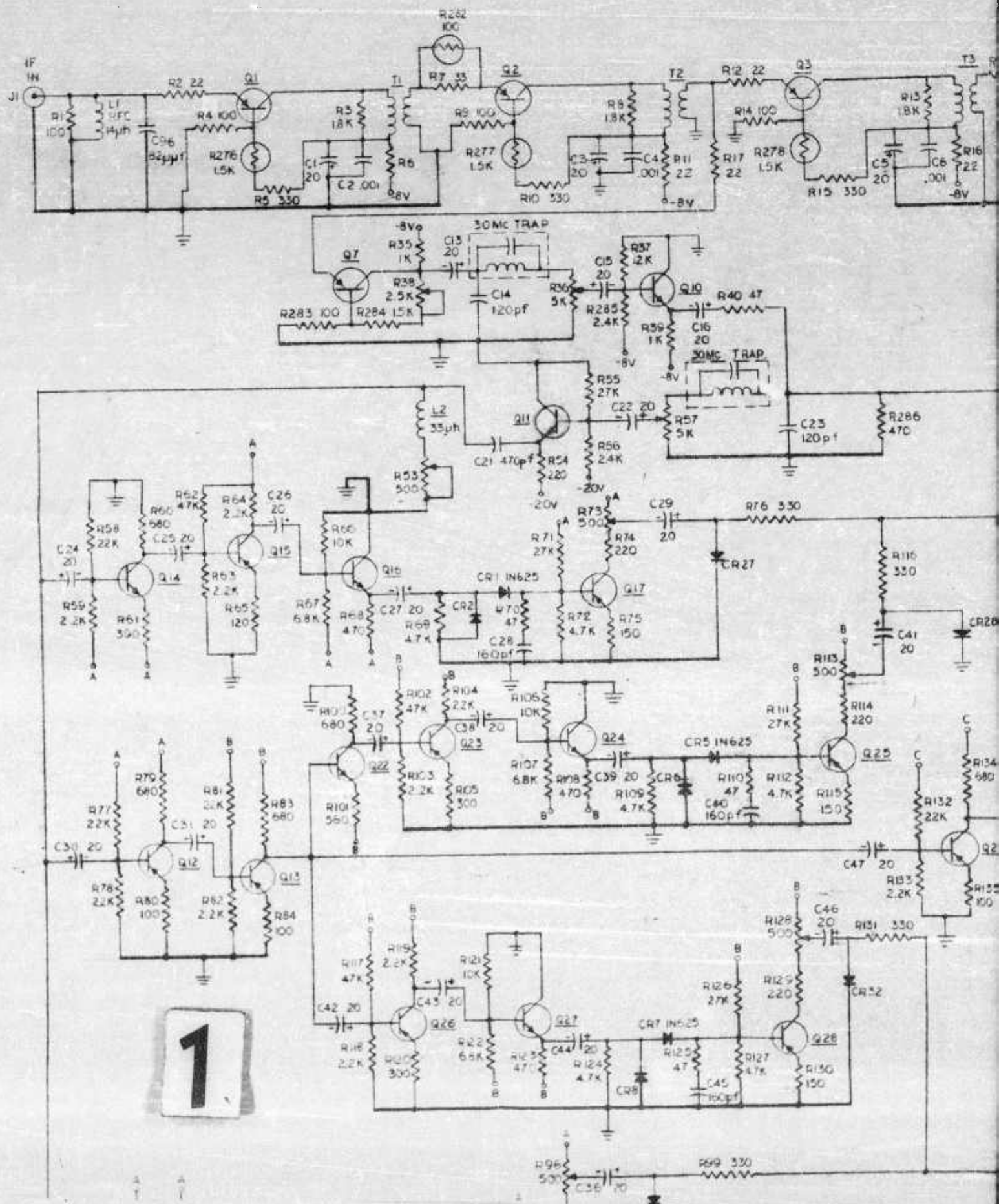
The CFAR check shall be performed as follows:

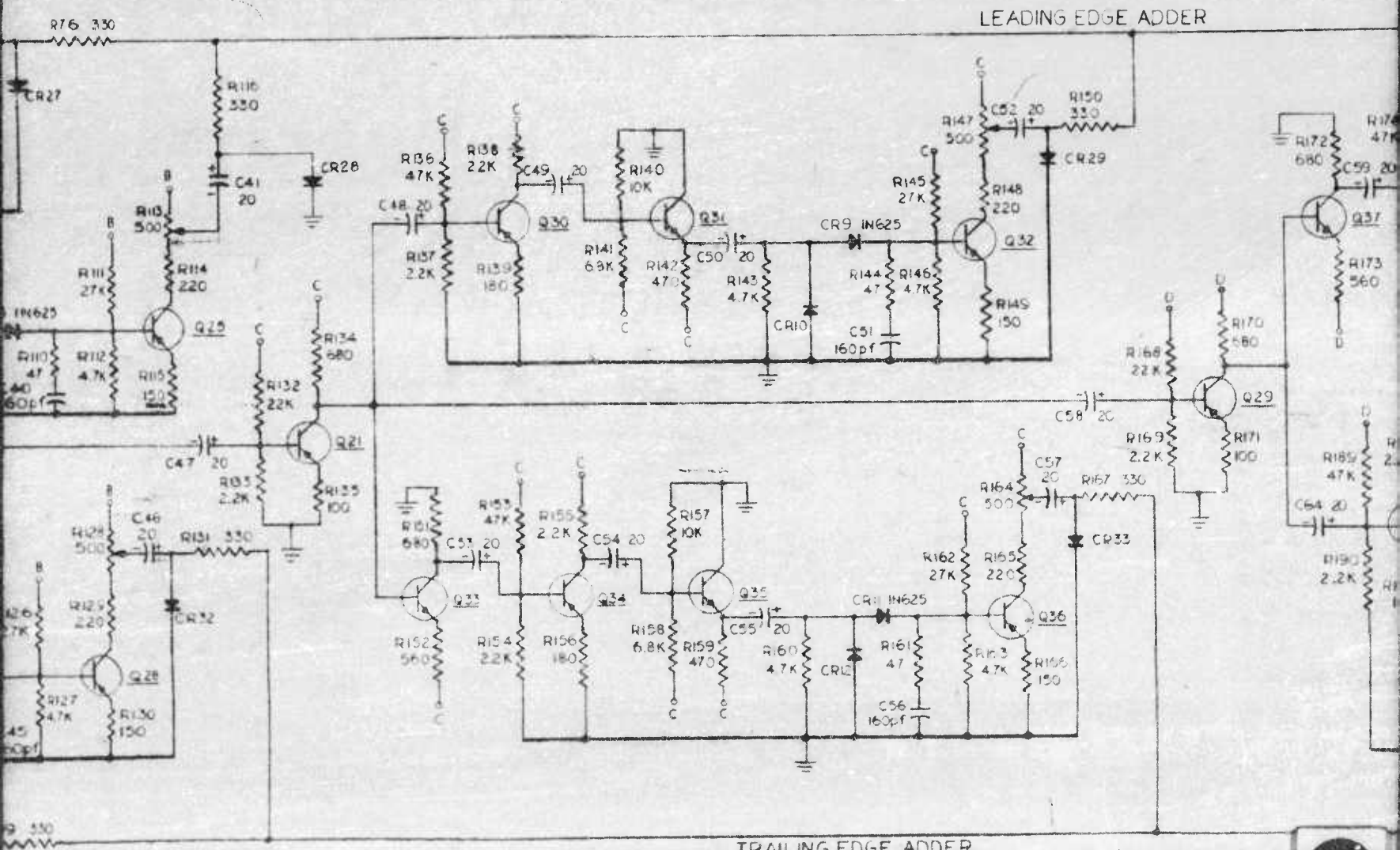
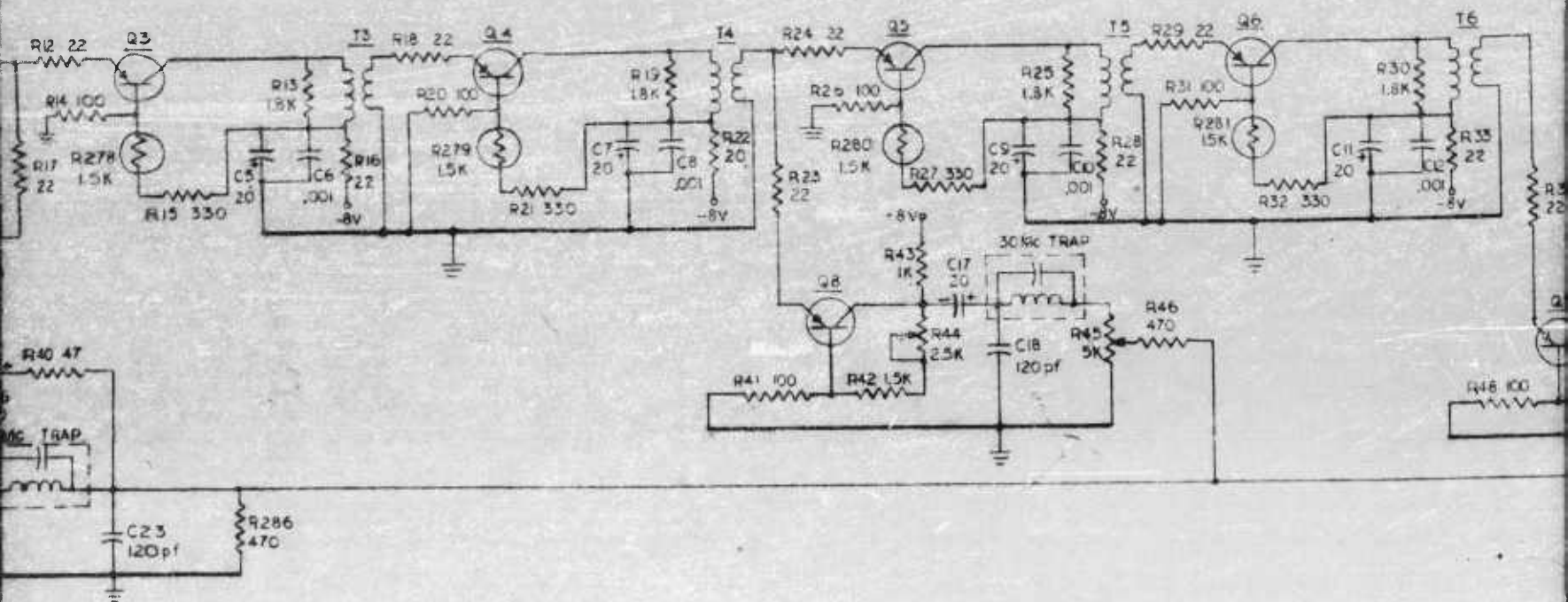
1. Vary the preamplifier bias. The noise level at the output should reach a maximum and then not increase further. (The character of the noise may change.)
2. If this is so, the CFAR section is operating properly. Set the preamplifier bias at the point where the noise just reaches maximum.
3. If the noise level continues to increase, set resistors R206 and R232 to maximum counterclockwise and follow steps 2 through 11 in section 3.4.4 (video CFAR adjustment).



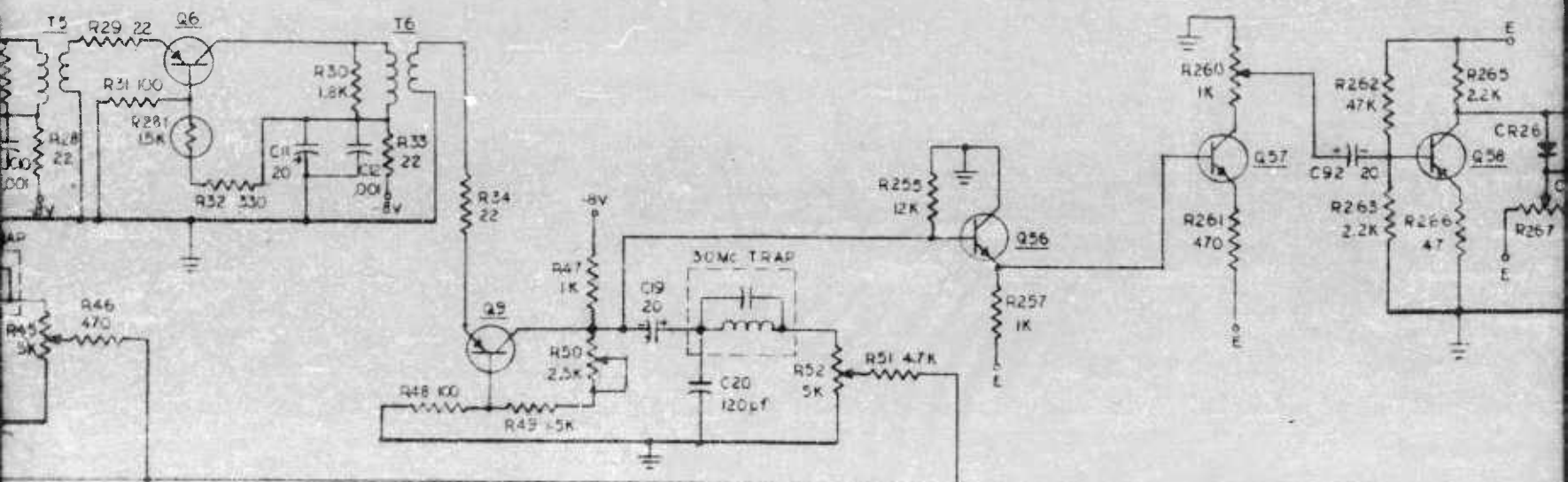
**Figure 6. ATC LINAR Receiver, Schematic Diagram**



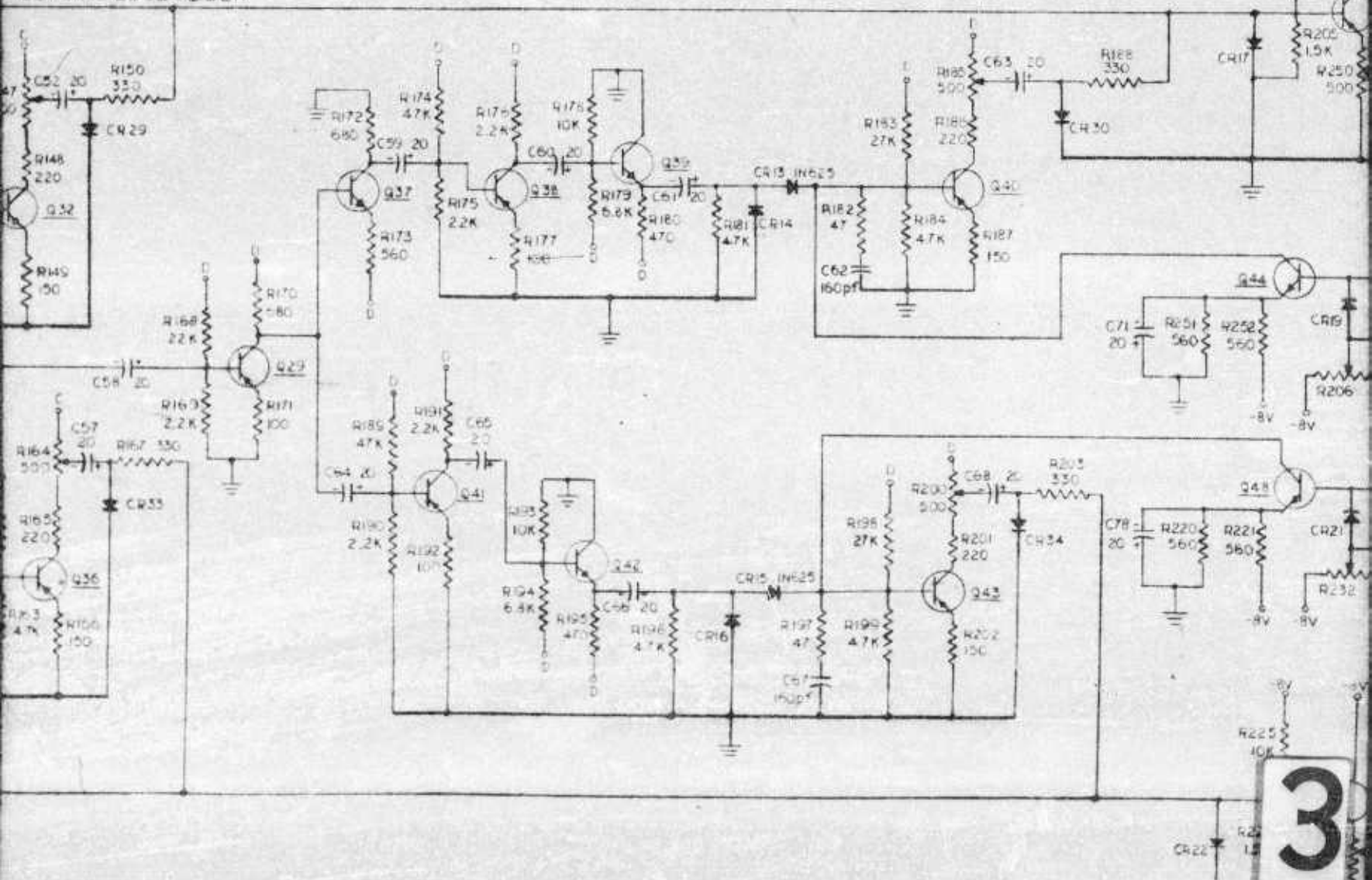




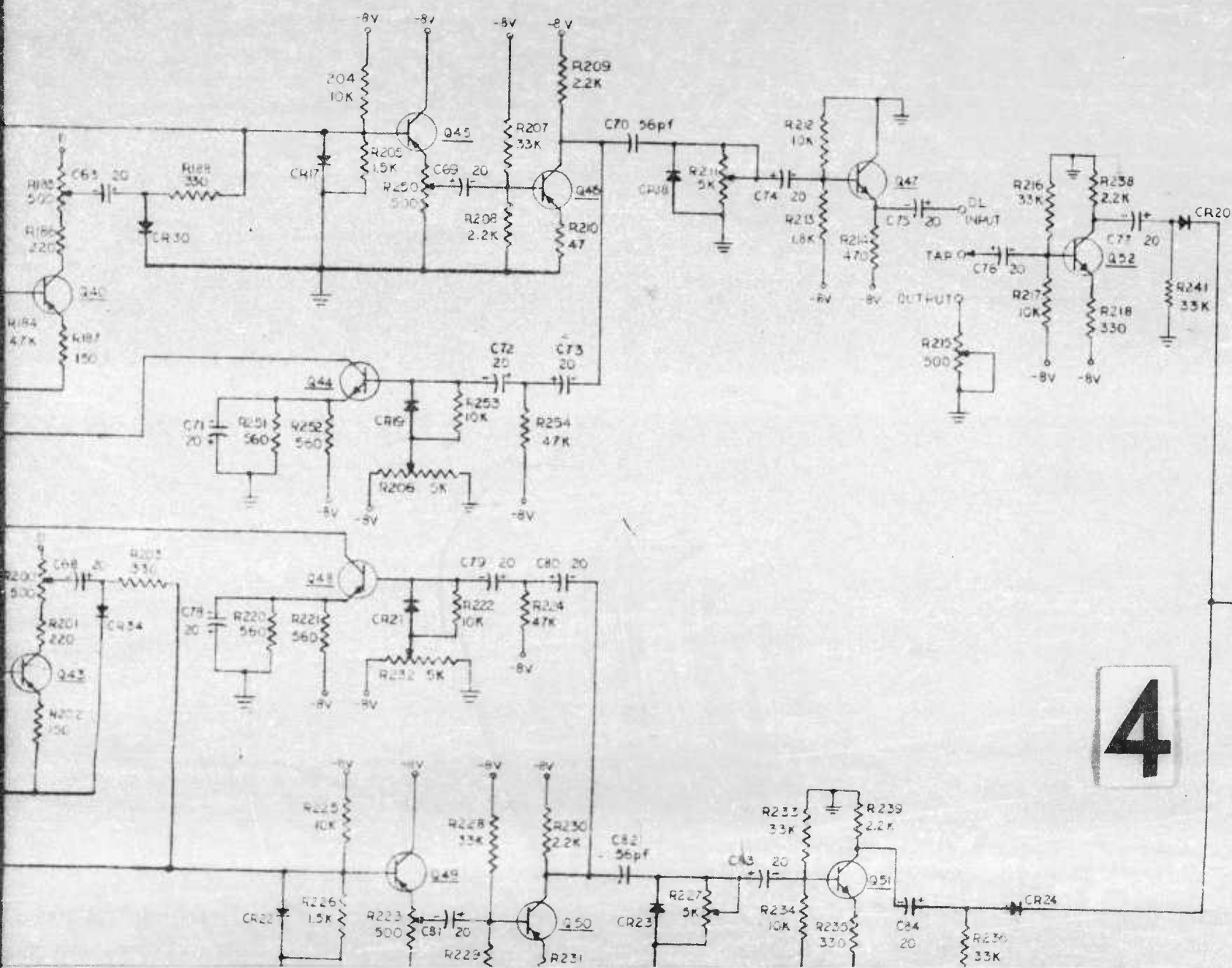
TRAILING EDGE ADDER



# LEADING EDGE ADDER

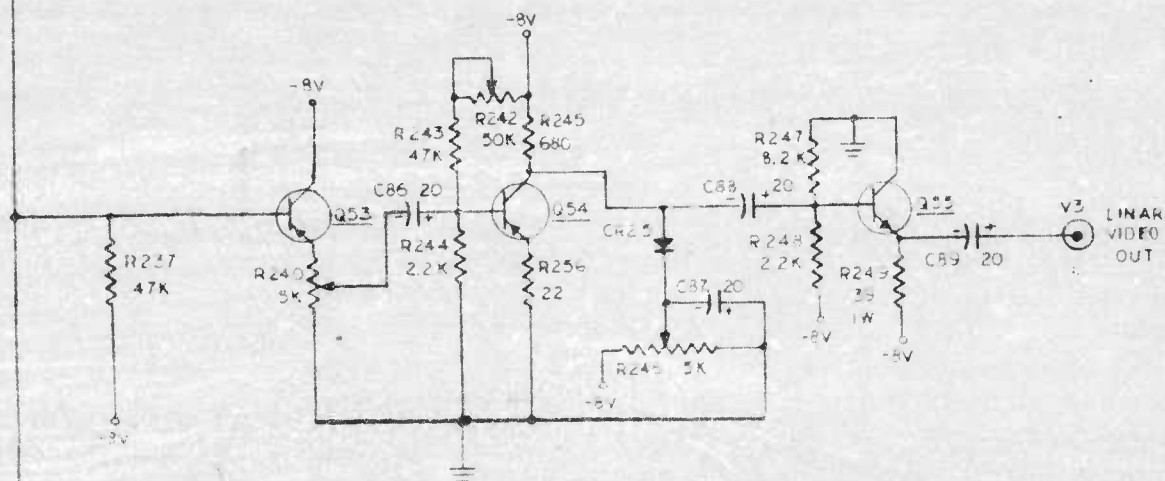
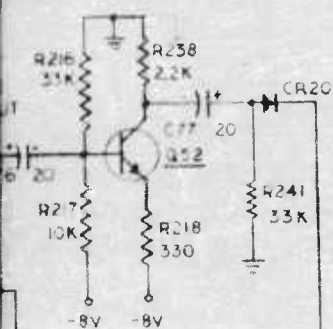






4





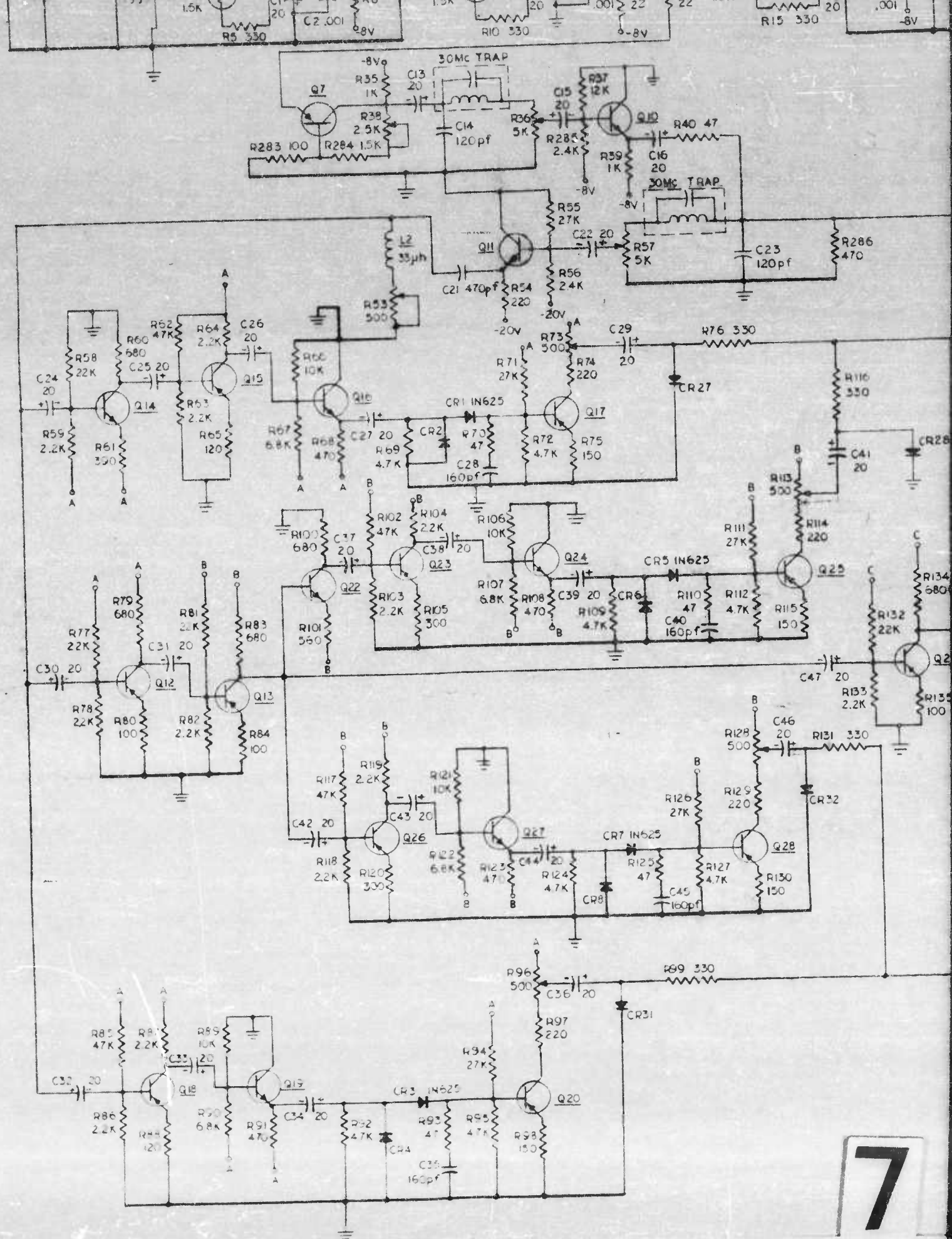
#### NOTES:

- 1-ALL PNP TRANSISTORS ARE TYPE 2N501/18.
- 2-ALL NPN TRANSISTORS ARE TYPE 2N706.
- 3-ALL CAPACITANCE IN MFD UNLESS OTHERWISE SPECIFIED.
- 4-ALL DIODES ARE TYPE 1N116 UNLESS OTHERWISE SPECIFIED.
- 5-R276 THRU R282 ARE TEMPERATURE VARIABLE RESISTORS.
- 6-VALVES SHOWN ARE FOR 25°C.



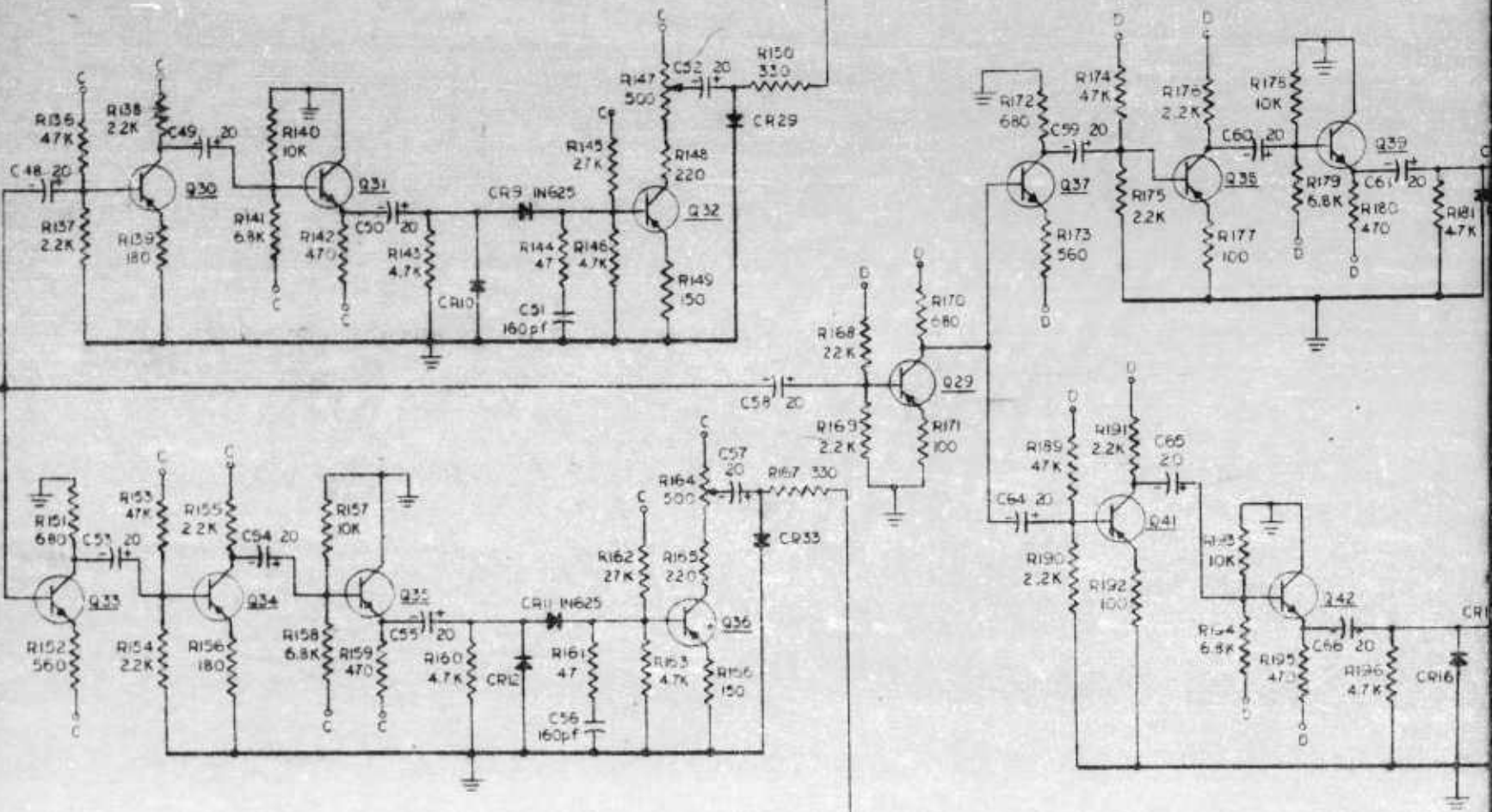
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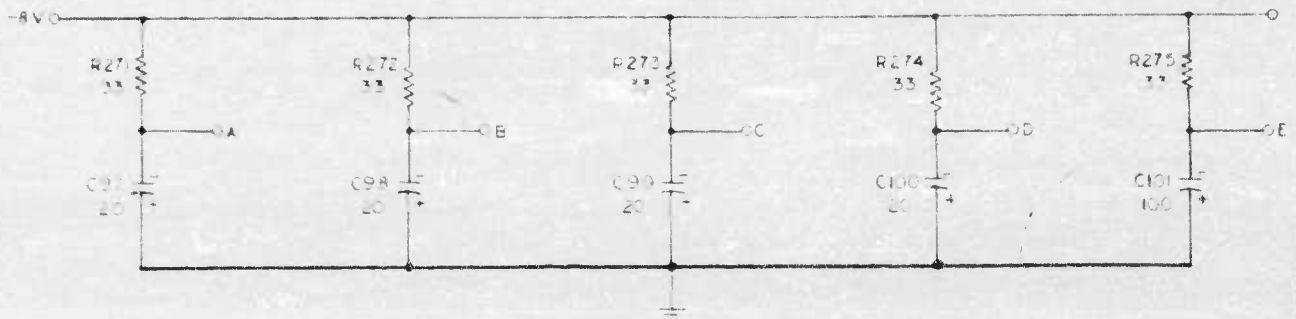




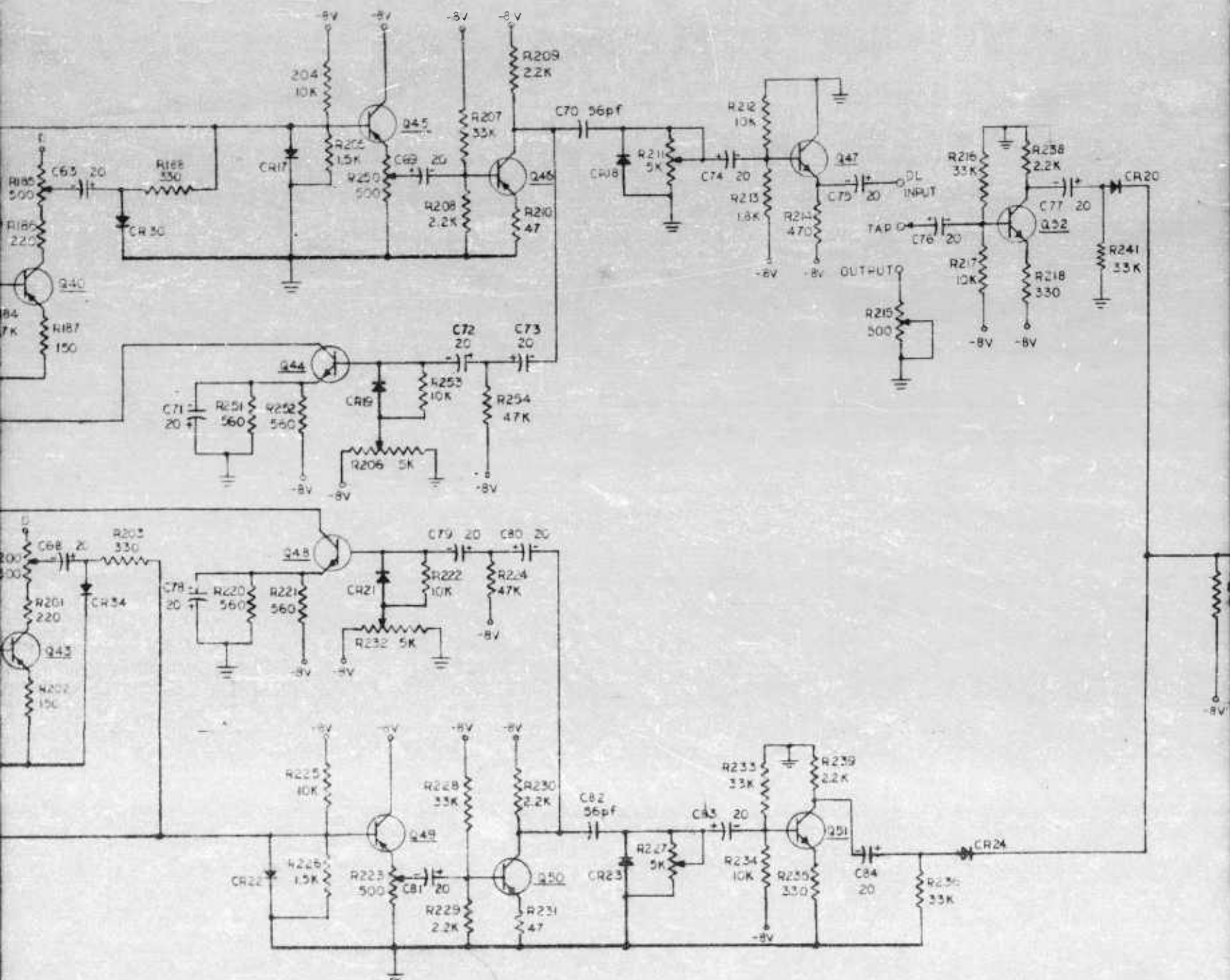
# LEADING EDGE ADDER

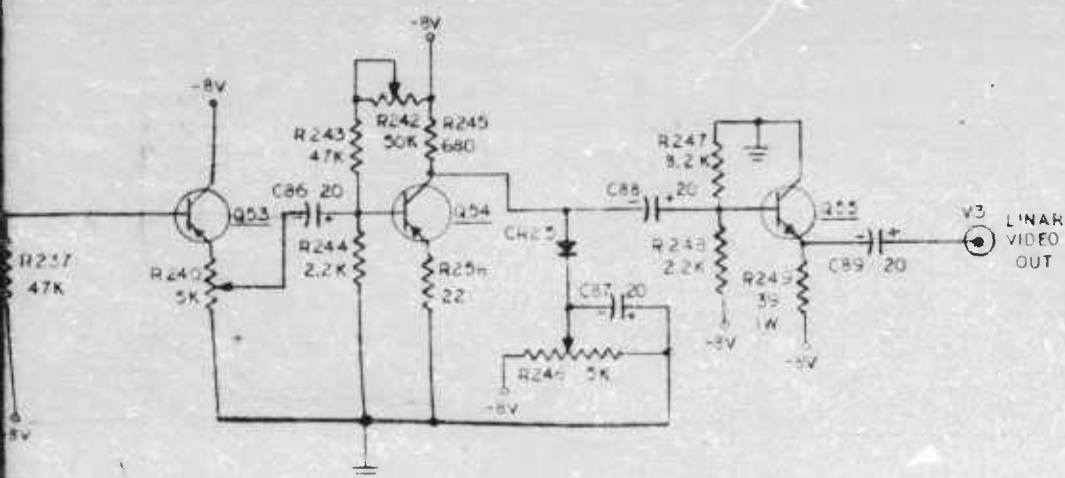


TRAILING EDGE ADDER









# NOTES:

- 1-ALL PNP TRANSISTORS ARE TYPE 2N501/18.
  - 2-ALL NPN TRANSISTORS ARE TYPE 2N706.
  - 3-ALL CAPACITANCE IN MFD UNLESS OTHERWISE NOTED.
  - 4-ALL DIODES ARE TYPE 1N116 UNLESS OTHERWISE NOTED.
  - 5-R276 THRU R282 ARE TEMPERATURE VARIABLE RESISTORS.
- VALVES SHOWN ARE FOR 25°C.

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NEXT ASSY	LINE 50N	D 5-B 122 1000000	SCHEMATIC DIAGRAM BENDIX ATC LINEAR RECEIVER	THE <b>Bendix</b> CORPORATION BENDIX RADIO DIVISION BALTIMORE 4, MARYLAND
APPLICATION				N16400